

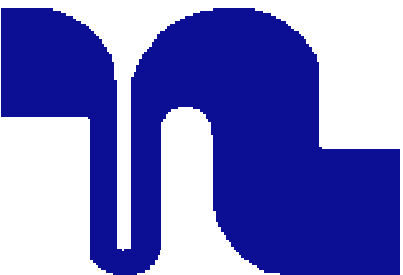
# **WATER (RESOURCE) CONSERVATION USING CLOSED-LOOP, EVAPORATIVE COOLING SYSTEMS FOR POWER PLANT APPLICATIONS**

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Energy-Water Needs Workshop – Eastern Region  
Baltimore, Md.

December 2005

Peter G. Demakos, P.E.  
Niagara Blower Co.  
Buffalo, NY



# **Agenda**

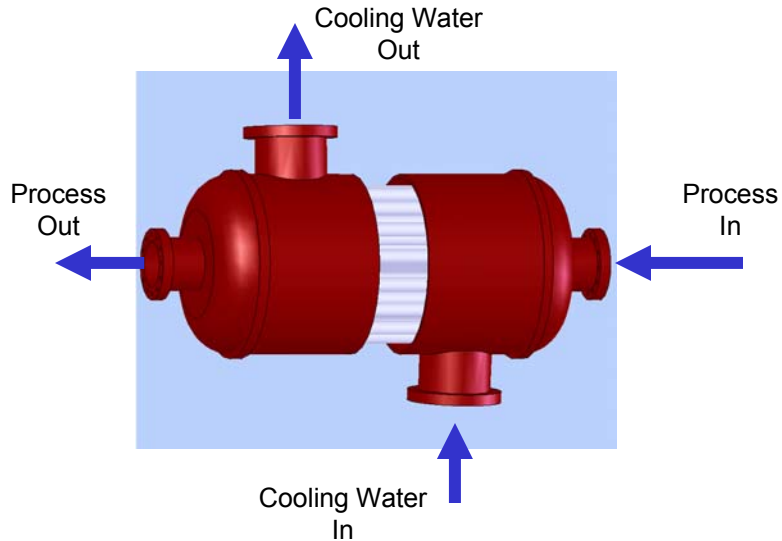
- **Closed Loop, Evaporative Cooler (Wet Surface Air Cooler Fundamentals)**
- **Water Issues**
- **Packaged and Field Erected Systems**
- **Advanced Cooling System Designs**
- **Case Studies**
- **Summary**

# **Wet Surface Air Cooler (WSAC)**

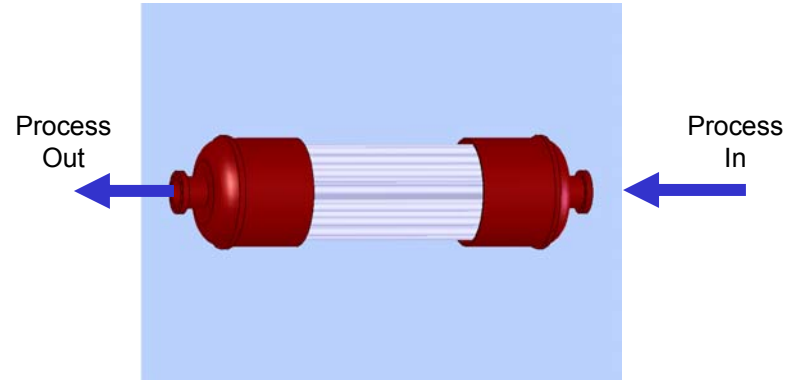
- What is it?
  - Heat Removal Device
- Where is it used in Power Plants?
  - Aux Loop Liquid Cooling
  - Turbine Exhaust Vacuum Steam Condensing
  - Inlet Air Refrigerant Condensing
- What are the benefits?
  - Poor quality water can be used as makeup
  - Reduces plant water requirements and discharge
  - Less HP required / more available power to grid

# How Does the WSAC Work?

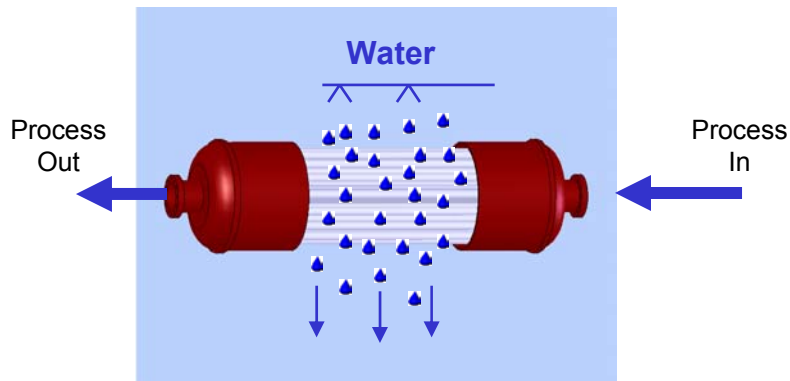
1.) Typical Shell & Tube Heat Exchanger



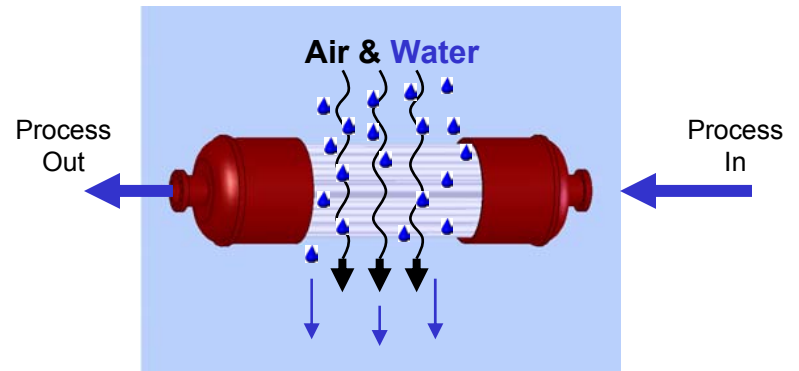
2.) Remove "Shell" Exposing Tubes



3.) Spray Water Directly Over the Exposed Tubes



4.) Air is Induced Over Tubes in the Same Direction as the Water



# How Does the WSAC Work?

✧ Heat is transferred from the cascading water to the air stream via vaporization

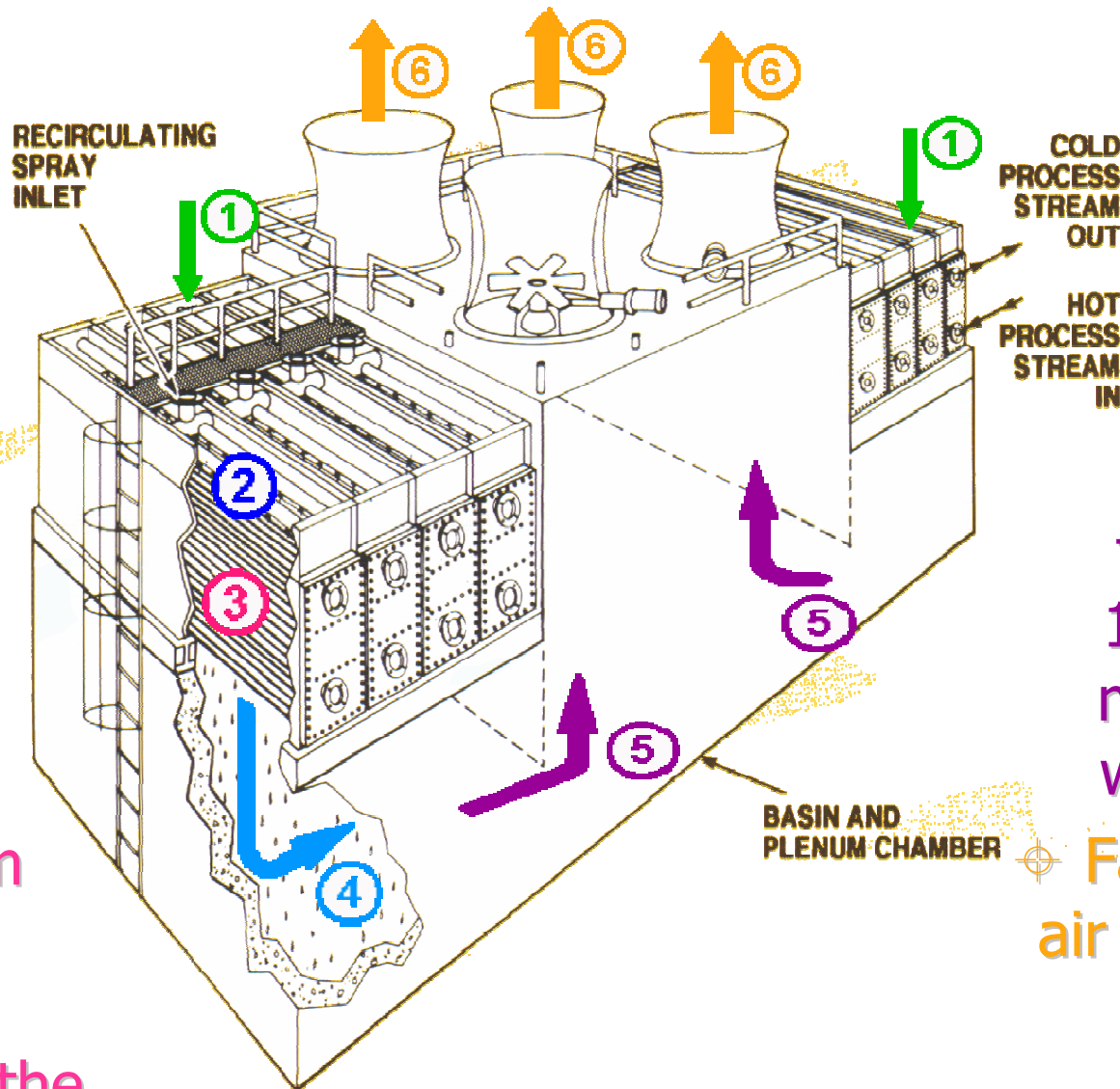
✧ Air stream forced to turn 180° providing maximum free water removal

✧ Fans discharge air vertically at a high velocity preventing recirculation

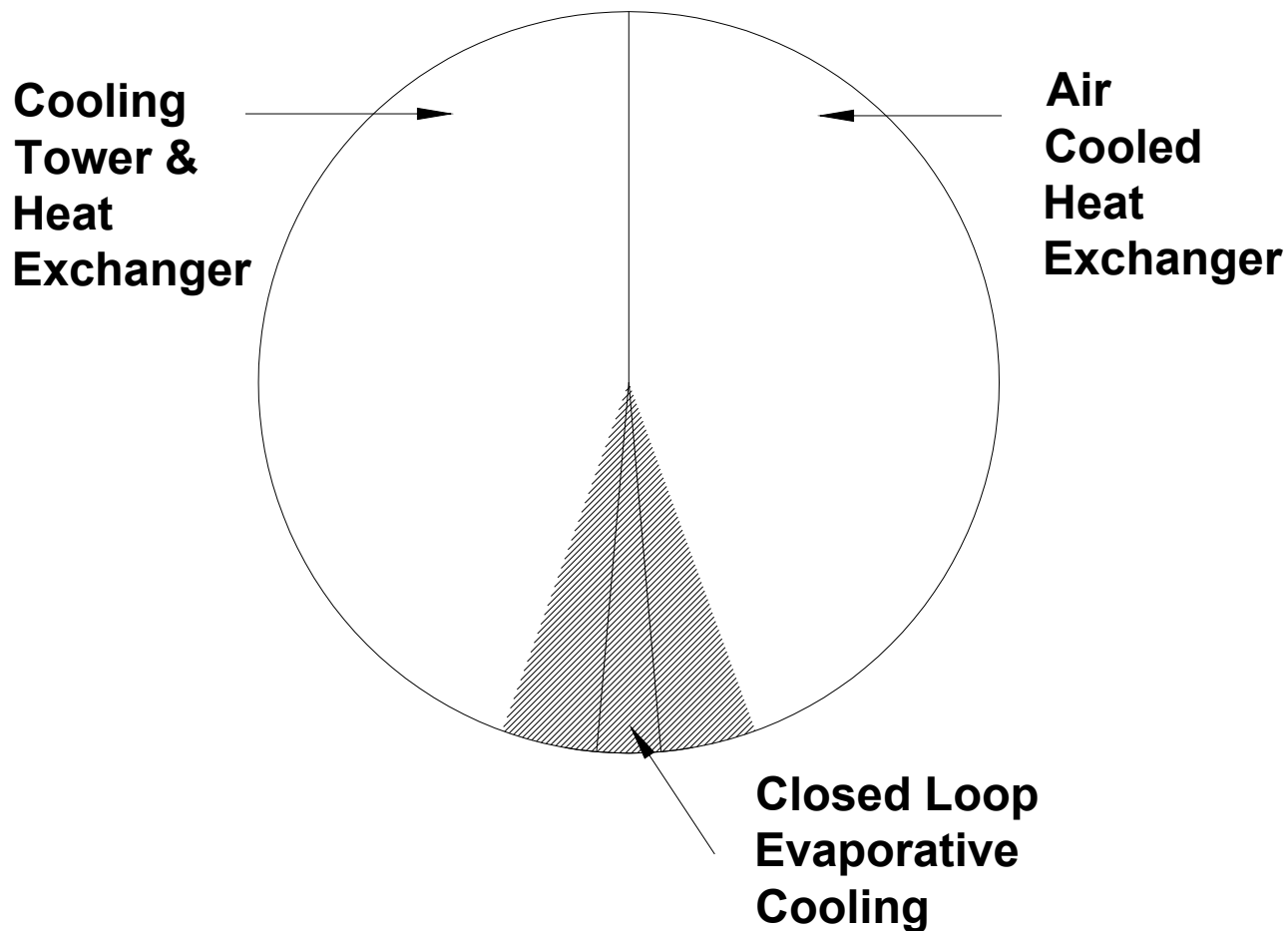
✧ Air is induced downward over tube bundles

✧ Water flows downward along with the air

✧ Heat from the process stream is released to the cascading water

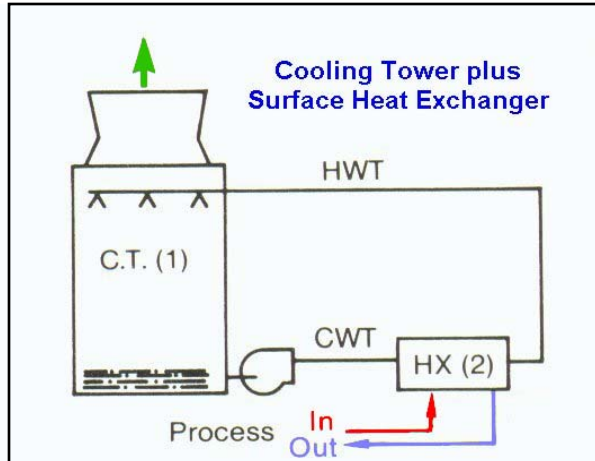


# **Breakdown of Current Industrial Cooling Technology**

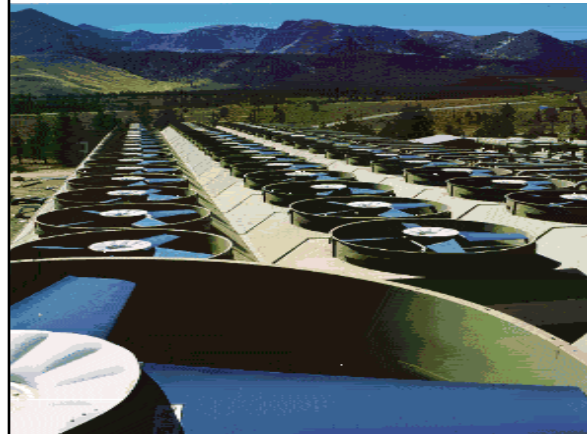
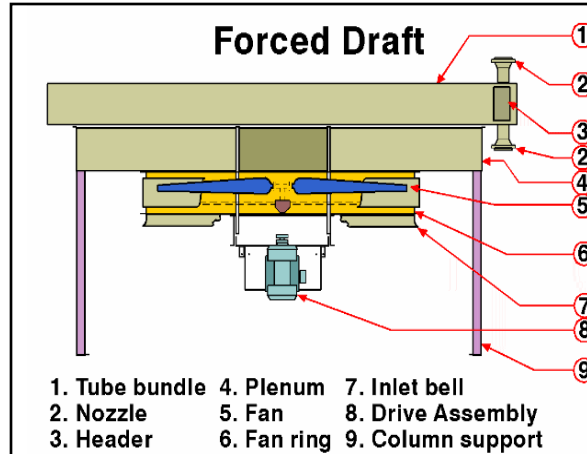


# 3 Cooling Technology Options

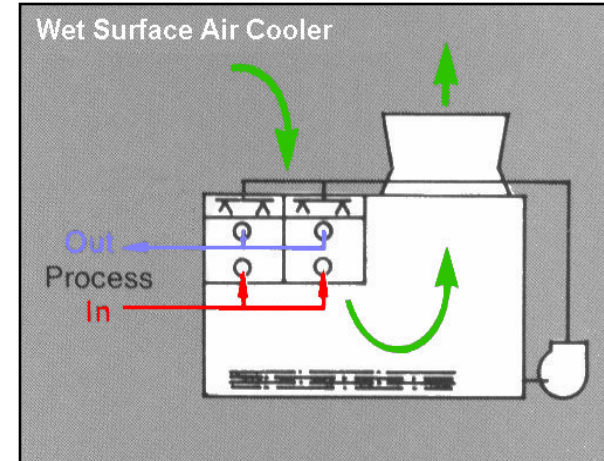
Cooling Tower / Heat Exchanger



Dry / Air Cooled



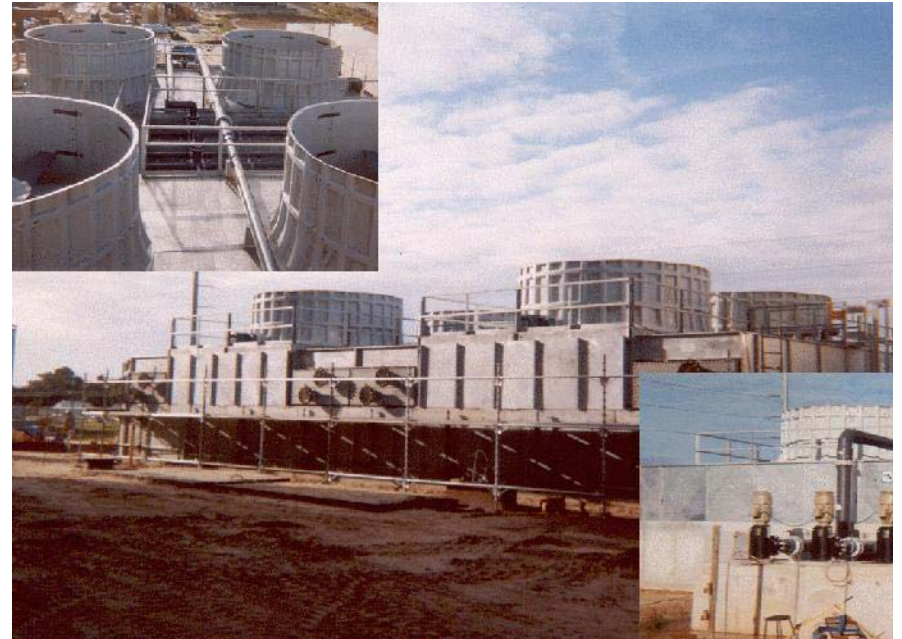
Wet Surface Air Cooler (WSAC)



# Unit Configurations



All Metal Unit

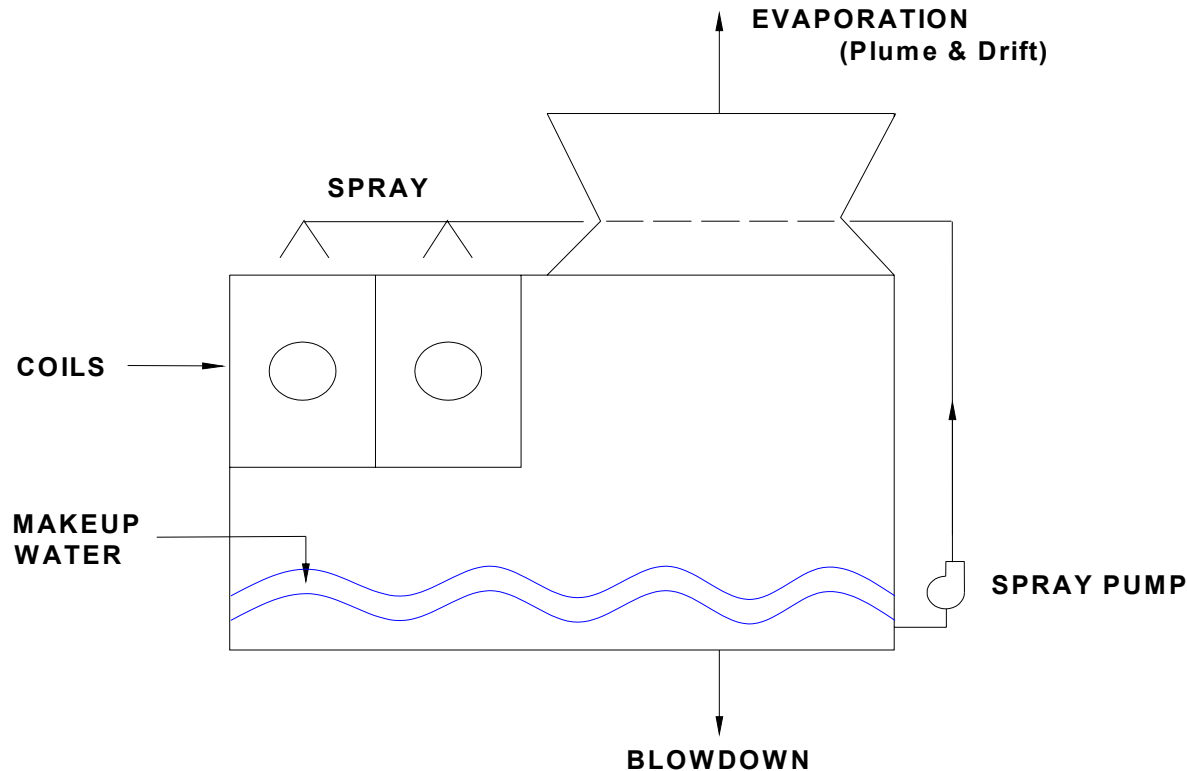


Field Erected Unit

# **Water Issues**

- **Evaporation**
- **Cycles of Concentration**
- **Drift**
- **Plume**
- **PM10**
- **Water Makeup**

# Water Issues



$$\text{EVAPORATION (GPM)} = \text{HEAT LOAD (Btu/hr)} / 500,000$$

$$\text{MAKEUP} = \text{EVAPORATION} + \text{BLOWDOWN}$$

$$\text{CYCLES OF CONCENTRATION} = \text{MAKEUP} / \text{BLOWDOWN}$$

# General Specifications for WSAC

- Spray Water Distribution System
  - Low-pressure / High-flow design
  - Full flooded spray pattern
  - Heavy duty construction
    - PVC pipe for assembled on site units



# Water Issues

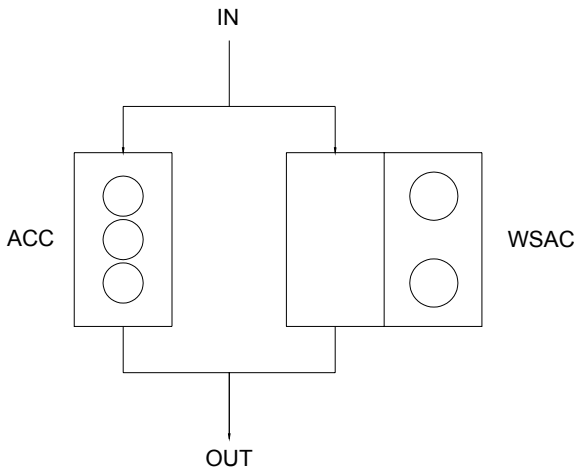
- Drift
  - Based on Spraywater Rate
  - “Standard” drift .02% / .005% standard (with drifts)
- Plume
  - Visual Discharge: Vapor Condensing in Atmosphere
  - Plume Abatement for Visually / Environmentally Sensitive Areas
- PM10
  - WSAC Meets or Exceeds PM 10 Requirements up to 10 mmeters
  - Lower Total Emissions / Lower Discharge Height

# **Water Issues**

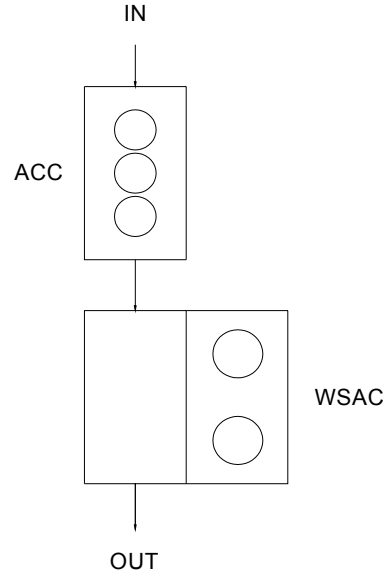
- Water Makeup
  - Blowdown from Cooling Towers and Boilers
  - Waste streams from Demineralizers, HRSG and RO
  - Waste Treatment Plant Effluent
  - Brackish, Seawater

# Wet / Dry System Options for Water Limited Plants

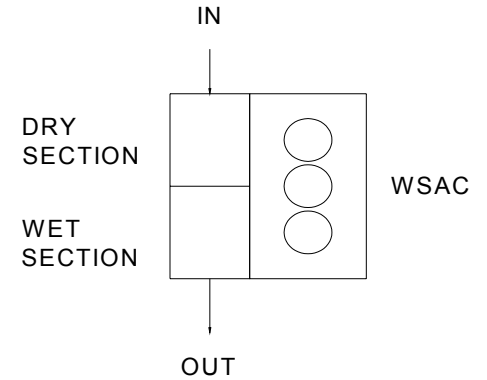
PARALLEL FLOW



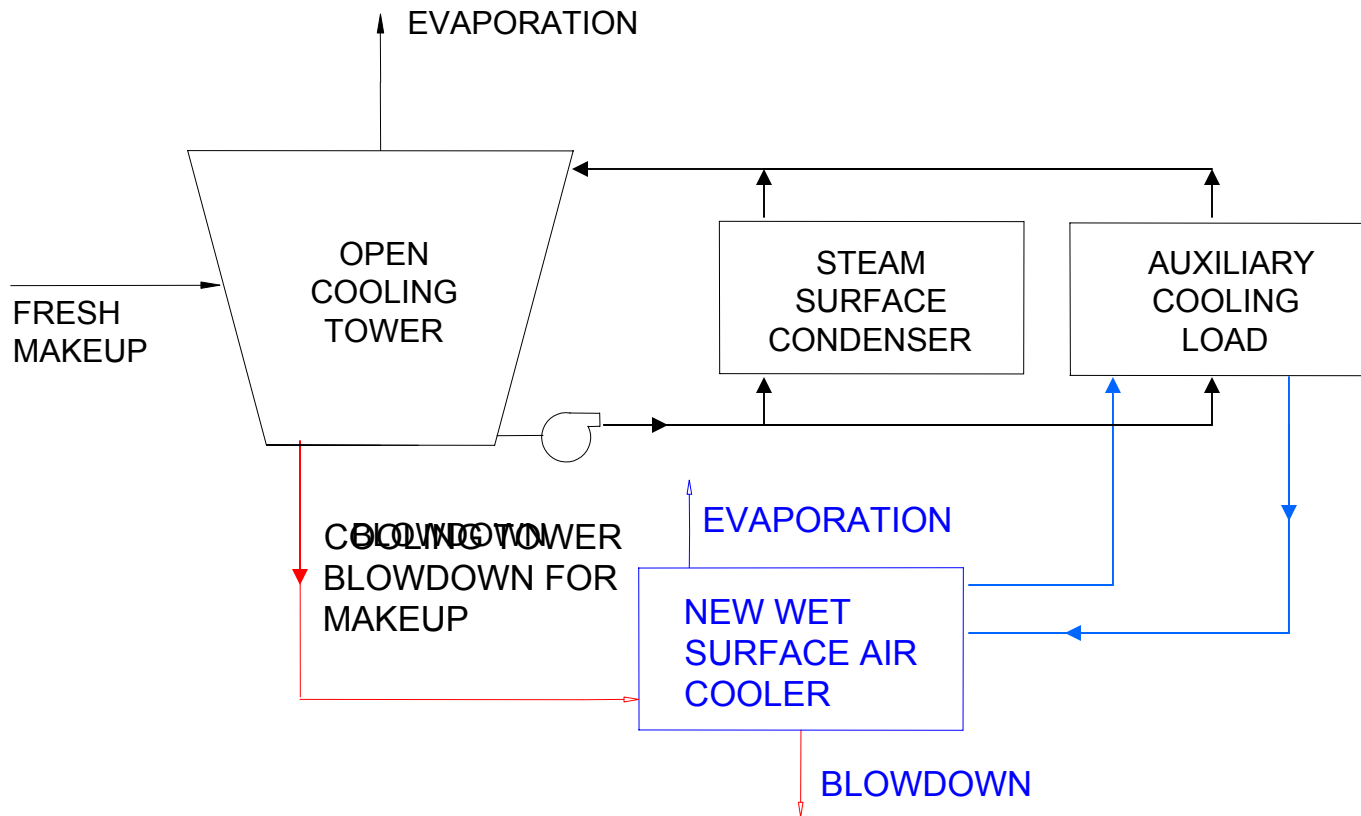
SERIES FLOW



COMBINED FLOW



# Independent Steam Condensing and Aux Loop Cooling Systems



# Independent Steam Condensing and Aux Loop Cooling Systems

MAKEUP WATER SAVINGS

**63 MILLION gal/yr**

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BLOWDOWN WATER REDUCTION

**63 MILLION gal/yr**

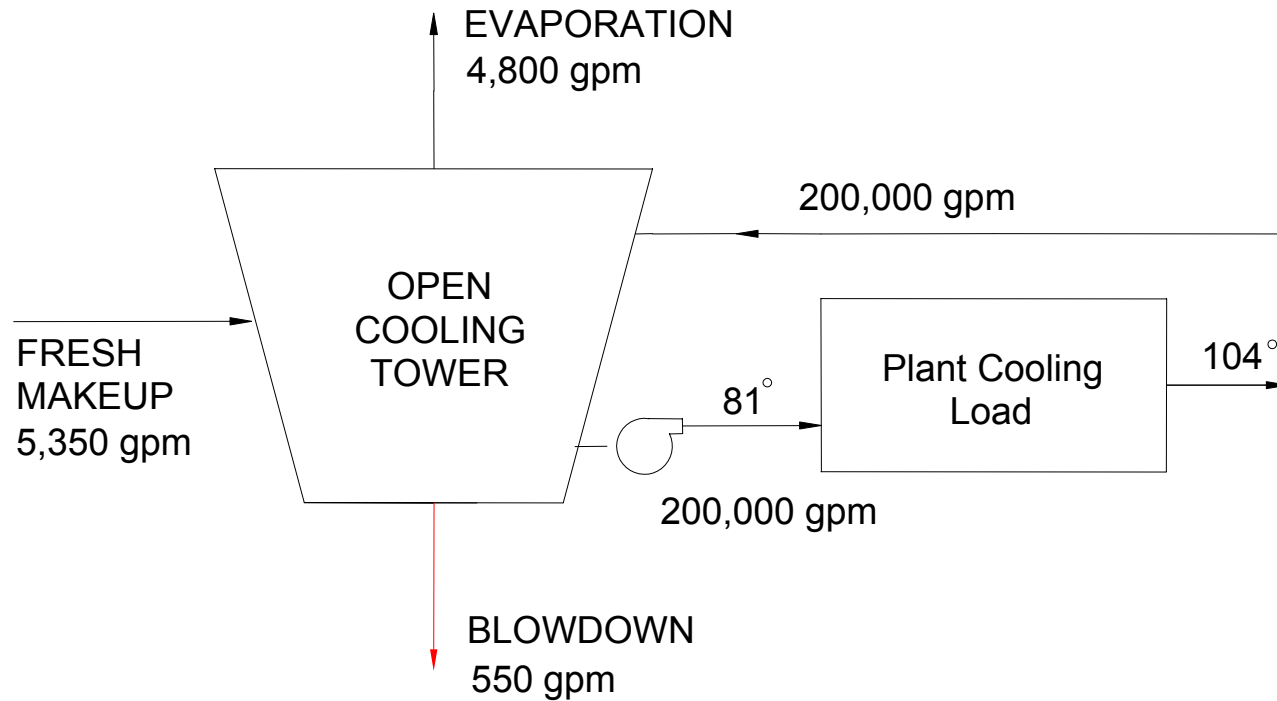
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PARASITIC ENERGY SAVINGS

**514 HP**

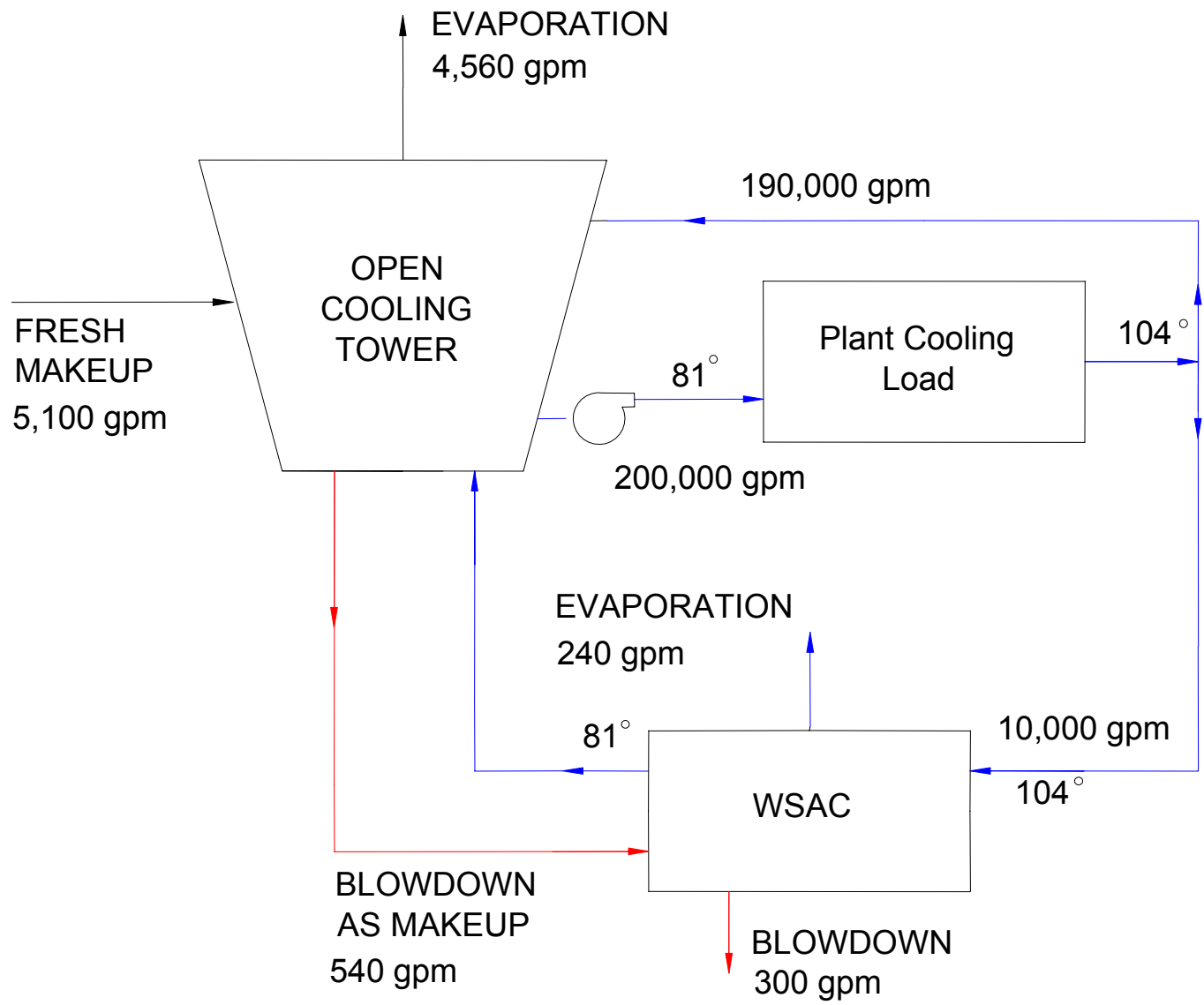
# Reducing Water Consumption in Existing Facilities

200,000 GPM - 104°F in / 81°F out



# Reducing Water Consumption in Existing Facilities

200,000 GPM - 104°F in / 81°F out



# **5% FRESH WATER REDUCTION**

## MAKEUP WATER SAVINGS

5,350 gpm → 5,100 gpm = 250 gpm

**120 MILLION gal/yr**

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## BLOWDOWN WATER REDUCTION

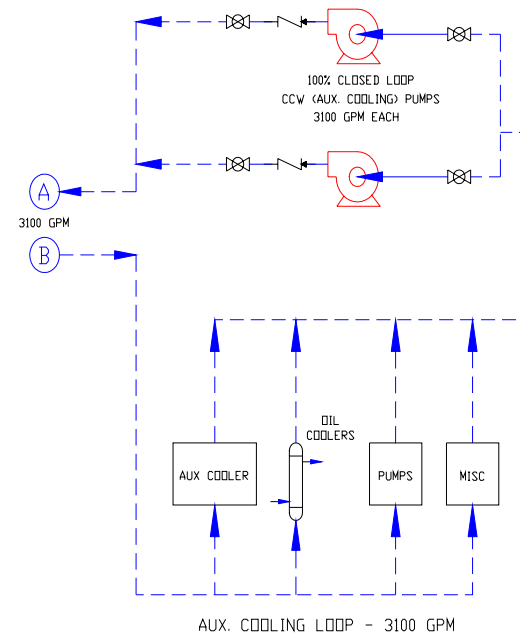
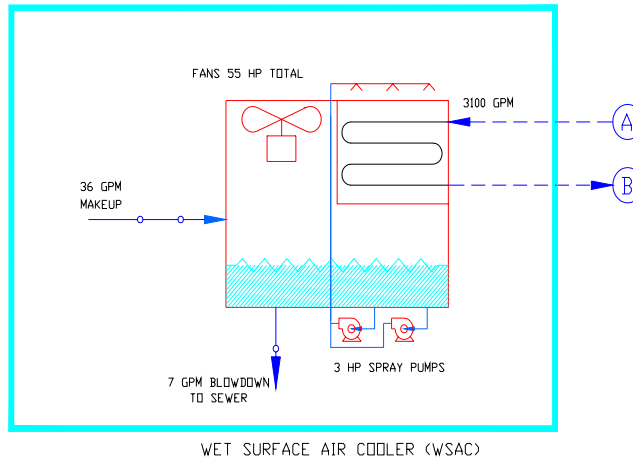
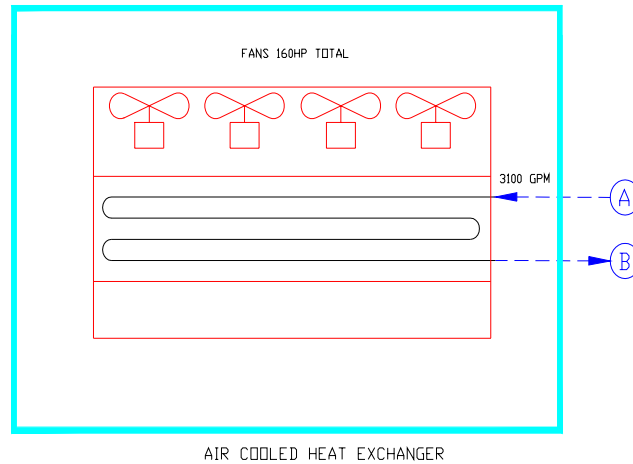
550 gpm → 300 gpm = 250 gpm

**120 MILLION gal/yr**

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\$\$ COSTS FOR:  
WATER ...DISPOSAL...TREATMENT

# AIR COOLED HEAT EXCHANGER VS. WSAC FLUID COOLER



| REVISION | LOCATION | DATE | BY | REVISION OR ADDITION |
|----------|----------|------|----|----------------------|
|          |          |      |    |                      |

Niagara Blower, Niagara Blower 3/29/2000 3:10 PM CASE\_STUDY\_#2NEW\_SHT.2.dwg

|                           |         |                      |  |
|---------------------------|---------|----------------------|--|
| APPROVAL SIGNATURES       | DATE    | CUST. P.O. NO.       |  <b>Niagara Blower Company</b><br>ENGINEERED HEAT TRANSFER SYSTEMS<br>BUFFALO, NEW YORK |
| DRAWN BY DDL              | 3/28/00 | SERIAL NO.           |  |
| CHECKED BY                |         | SHIP ORDER NO.       | (UNAUTHORIZED USE, MANUFACTURE, OR REPRODUCTION EITHER IN WHOLE OR PART IS PROHIBITED. DRAWING DESIGN AND OTHER DISCLOSURES PROPERTY OF NIAGARA BLOWER COMPANY.)             |
| ENGINEER                  |         | DIMENSIONS IN INCHES | <input checked="" type="checkbox"/> MILLIMETERS<br>TOLERANCES UNLESS OTHERWISE SPECIFIED<br>DECIMALS: .015" = .001"<br>ANGLES: ± 1/4°<br>FRACTIONS: ± 1/4"                   |
| RELEASED BY               |         | CUSTOMER             | TITLE: DUAL F CLASS COMBINED CYCLE POWER PLANT<br>CUSTOMER: NIAGARA AUXILIARY COOLING SYSTEM   |
| APPLICABLE SPECIFICATIONS |         | DWG. NO.             | SHEET NO. 1 OF 1<br>SCALE:   |

138

# AIR COOLED HEAT EXCHANGER VS WSAC

12,000 gpm flow rate

## PLOT AREA SAVINGS

8,000 FT<sup>2</sup> → 1900 FT<sup>2</sup> gpm

**75% LESS SPACE REQUIRED**

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## HORSEPOWER SAVINGS

640 HP → 200 HP

**450 LESS HP REQUIRED (70%)**

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## MAKEUP WATER REQUIRED

**128 gpm NEEDED**

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## LOWER INSTALLED COST

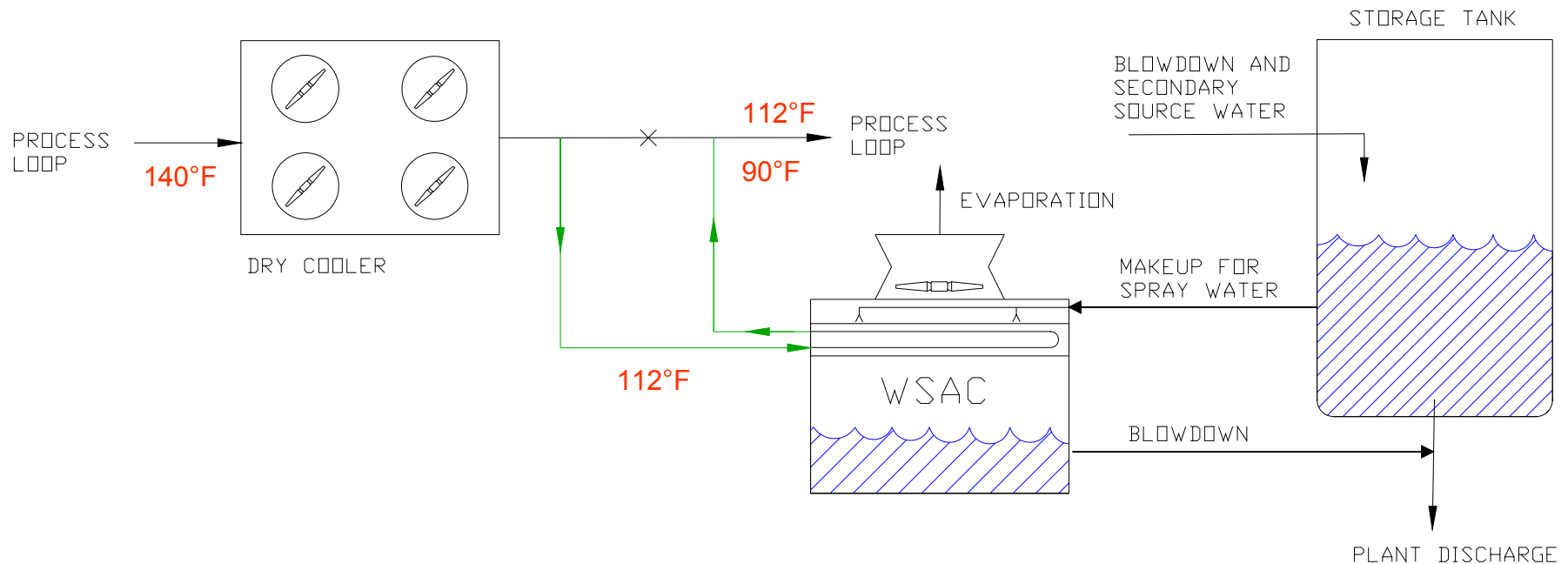
**60% LOWER COST**

# Lowering Process Outlet Temperatures

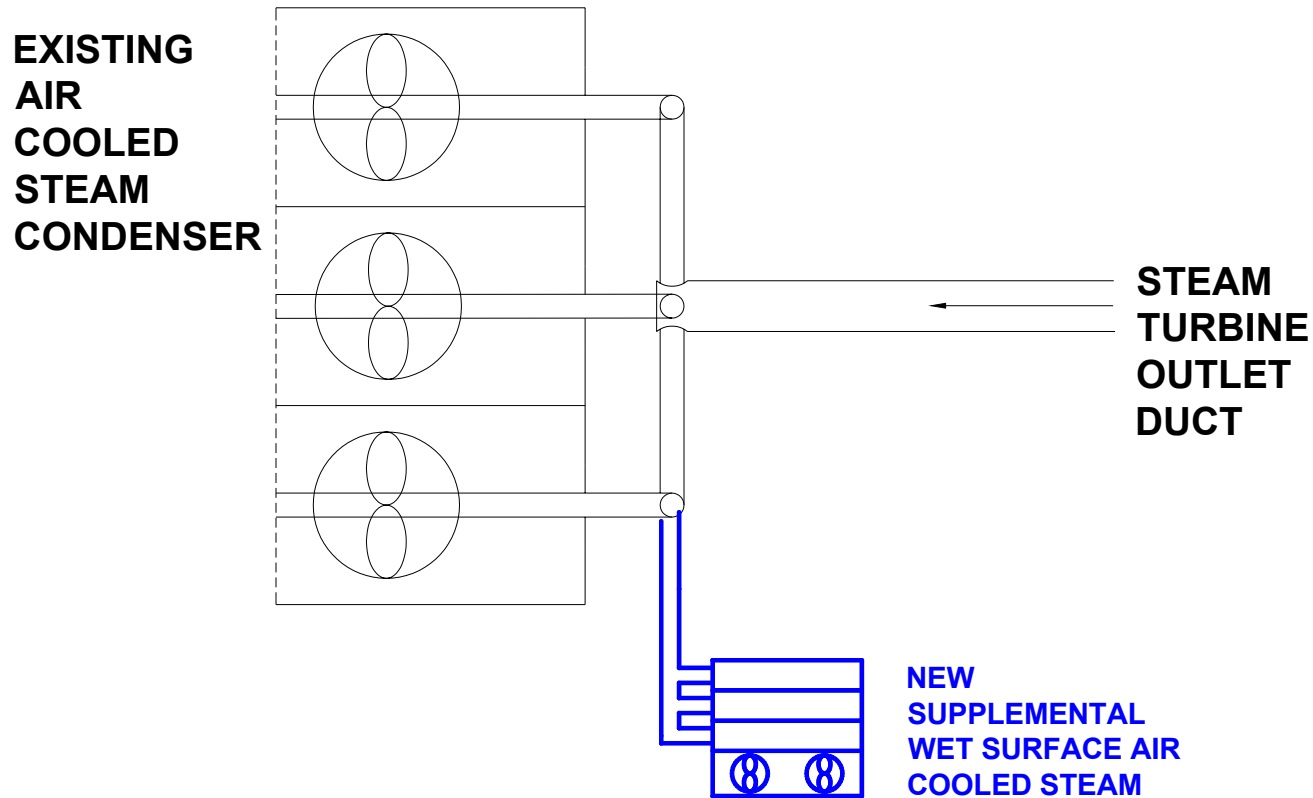
Ambient Conditions: 92°F Dry Bulb --- 80°F Wet Bulb

Process Loop Conditions: 140°F in --- 112°F out

**NEW Process Loop Conditions: 140°F in --- 90°F out**

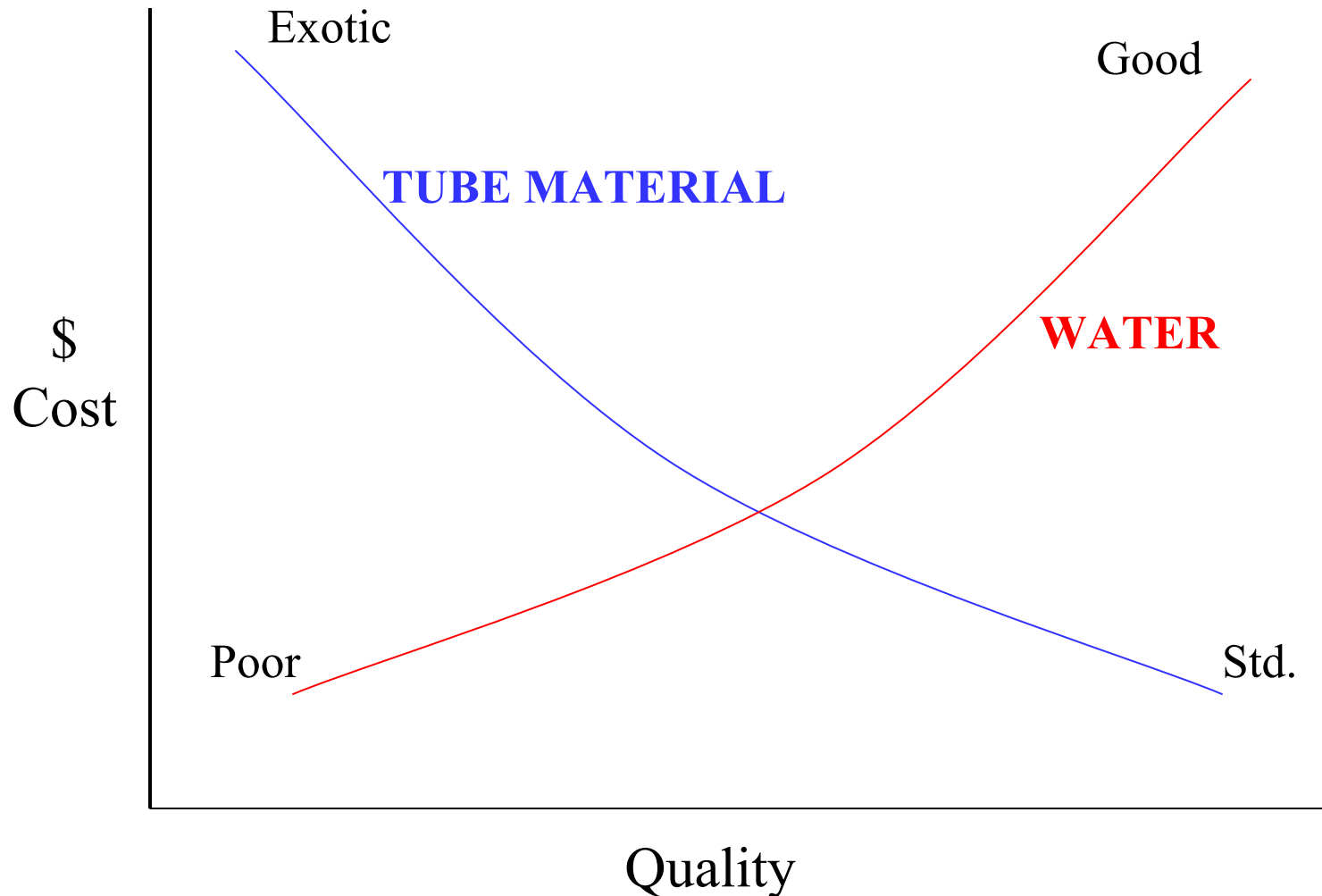


# De-Bottlenecking of Existing Air-Cooled Systems

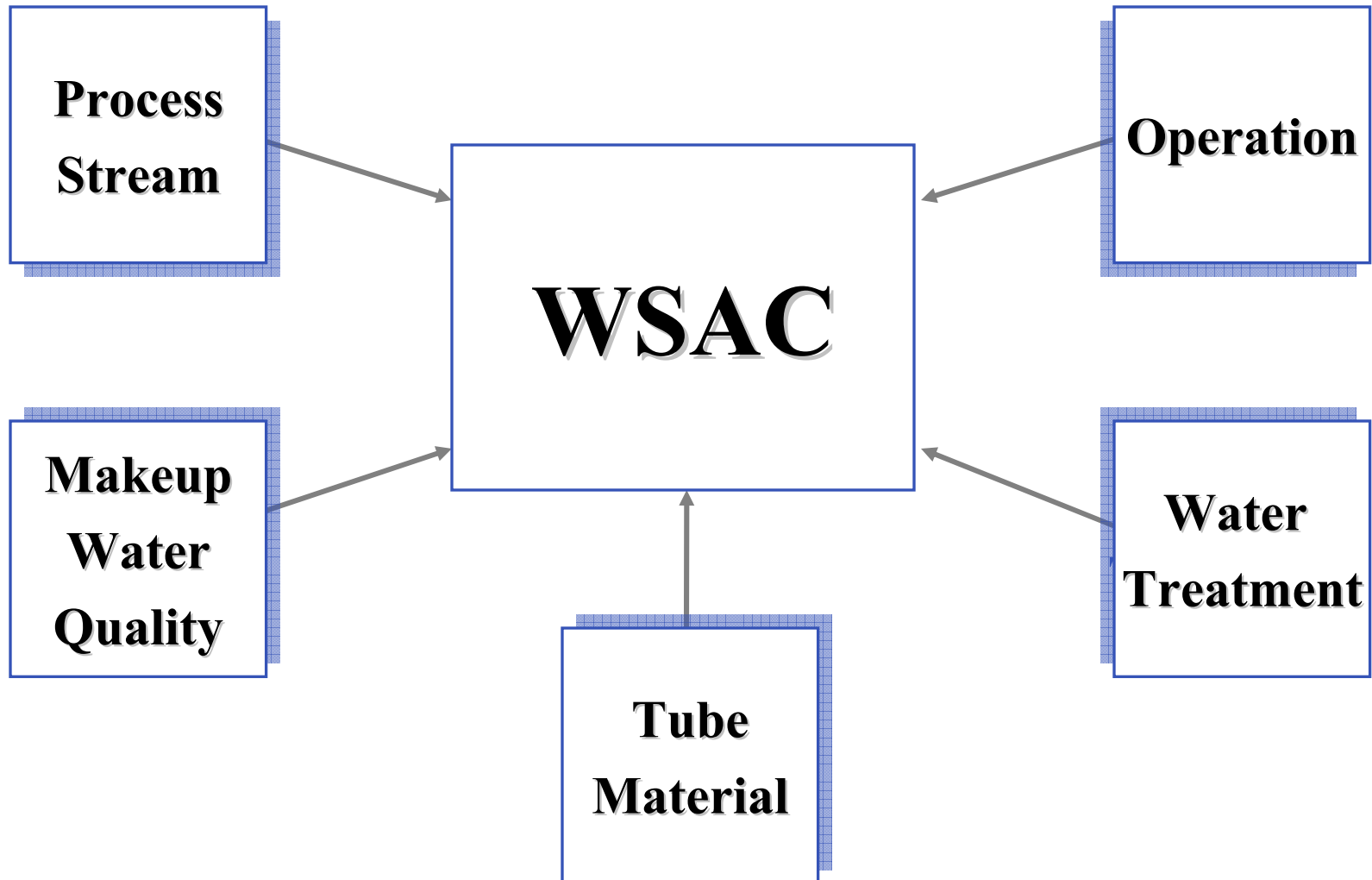


# Cost Analysis

## Water Quality & Tube Material



# Design Considerations



# **WSAC Demonstration Project**

## **New Mexico Power Plant**

- Funded by EPRI & DOE

- Kent Zammit, EPRI

- John Maulbetsch, Consultant

- Barbara Carney, NETL / DOE

- Mike DiFilippo, Consultant

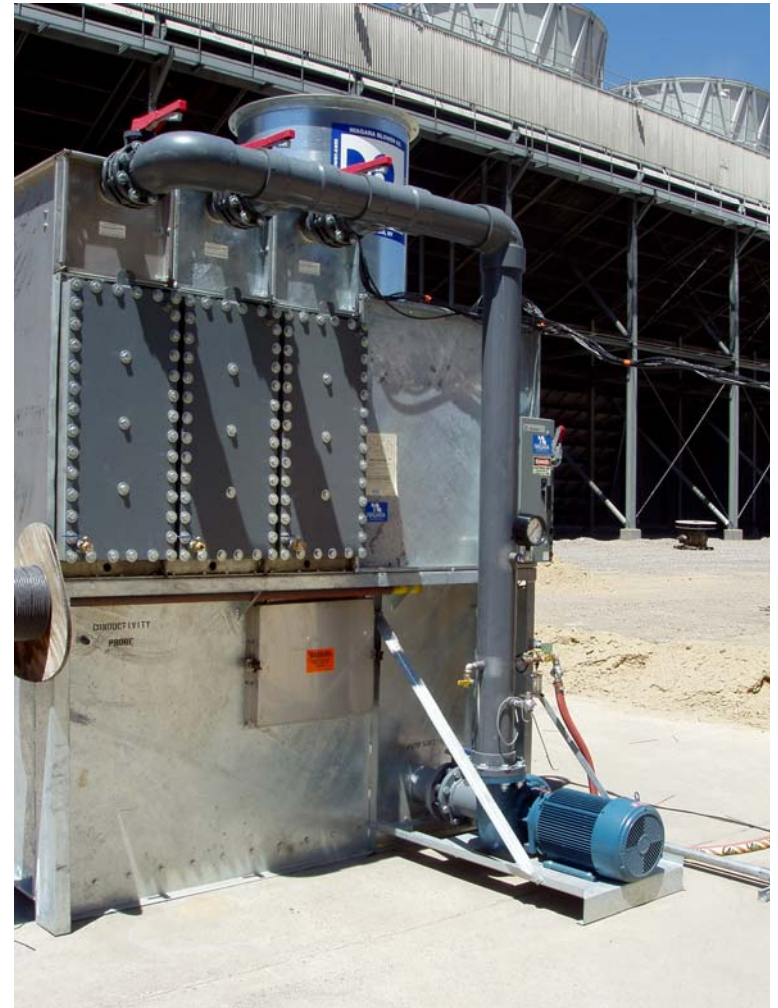
- Test water quality limits in a WSAC

- Monitor unit performance using cooling different sources of water as spray system makeup:

- 2005 Cooling Tower Blowdown (river water makeup)

- 2006 “Produced” Water from the Mining Process

# WSAC Demonstration Project



# **WSAC Demonstration Project**

## **New Mexico Power Plant**

- WSAC unit built with different tube materials:
  - Duplex Stainless; 90/10 Cu-Ni; Titanium; “Sea Cure”
- Operating at 35 – 50 cycles of concentration using cooling tower blowdown as WSAC makeup
- NO DEGRADATION OF THERMAL PERFORMANCE**

# **INSTALLATIONS**

# Packaged Water Cooler



# Aux Cooler for 4 – 50 MW Gas Turbines

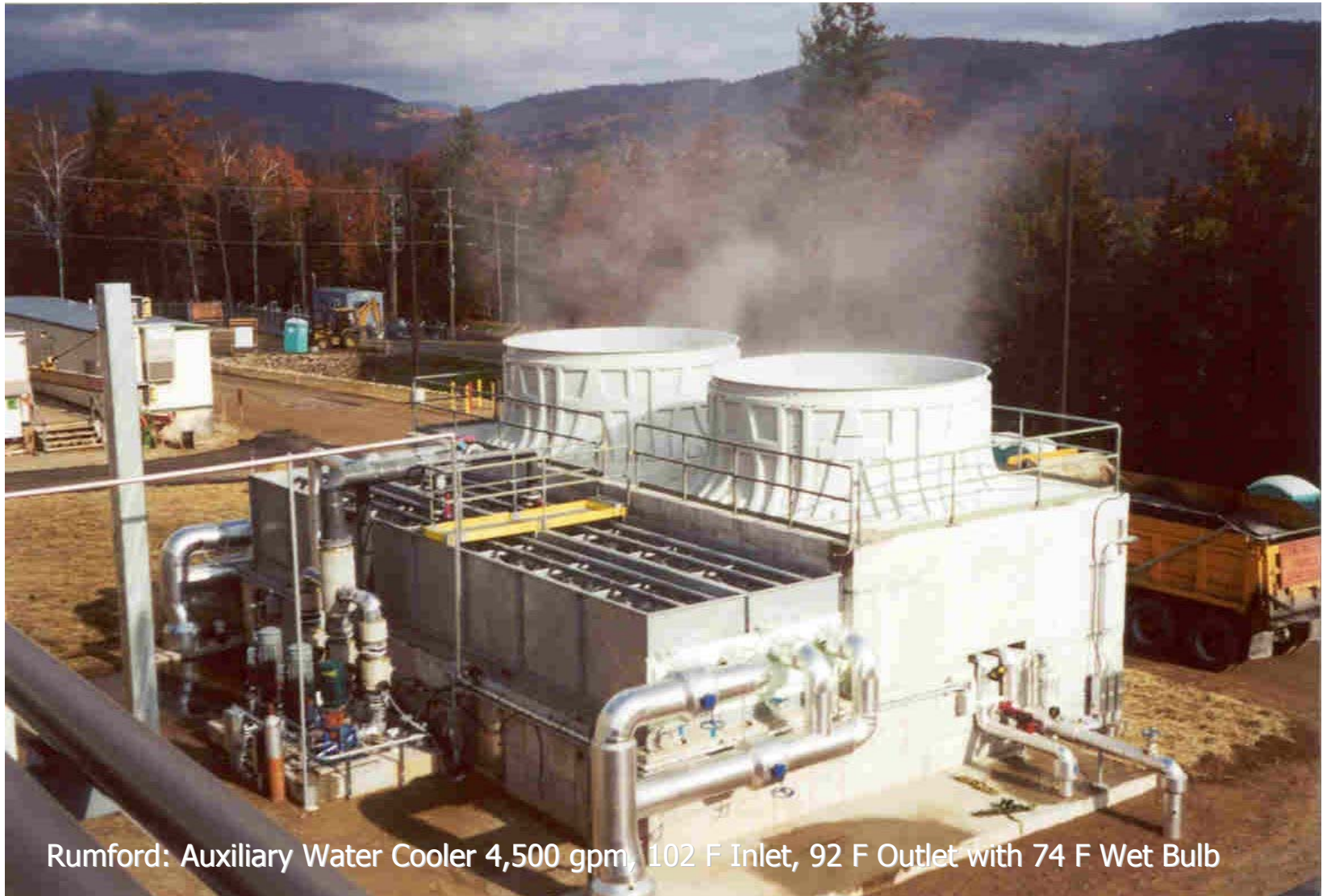
## With 50% Reserve Capacity



# Factory Assembled Frame Turbine Auxiliary Fluid Cooler



# LARGE ERECT IN PLACE WSAC FLUID COOLERS



Rumford: Auxiliary Water Cooler 4,500 gpm, 102 F Inlet, 92 F Outlet with 74 F Wet Bulb



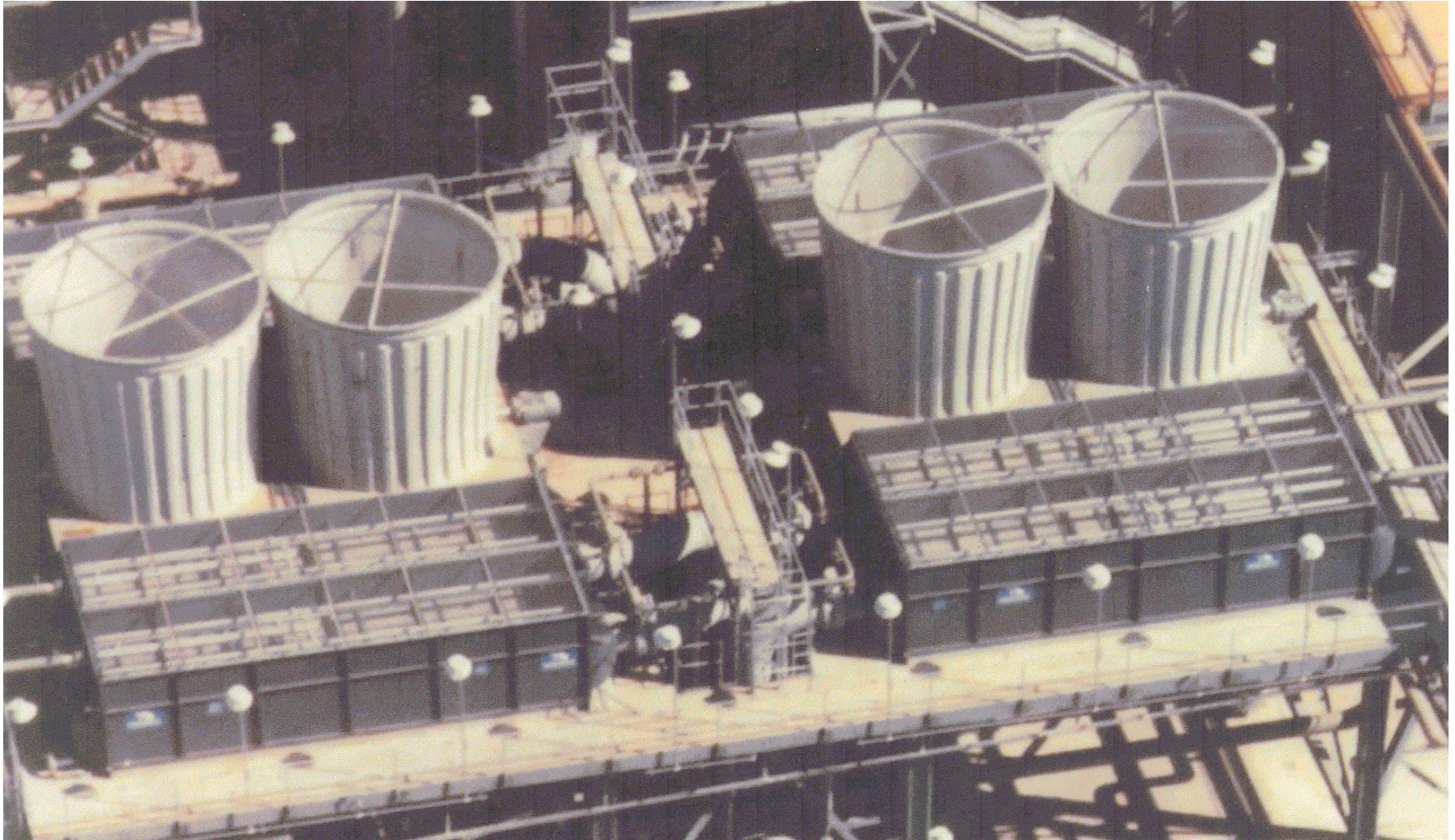
**HRSG**

**WSAC  
AUX LOOP  
COOLER**

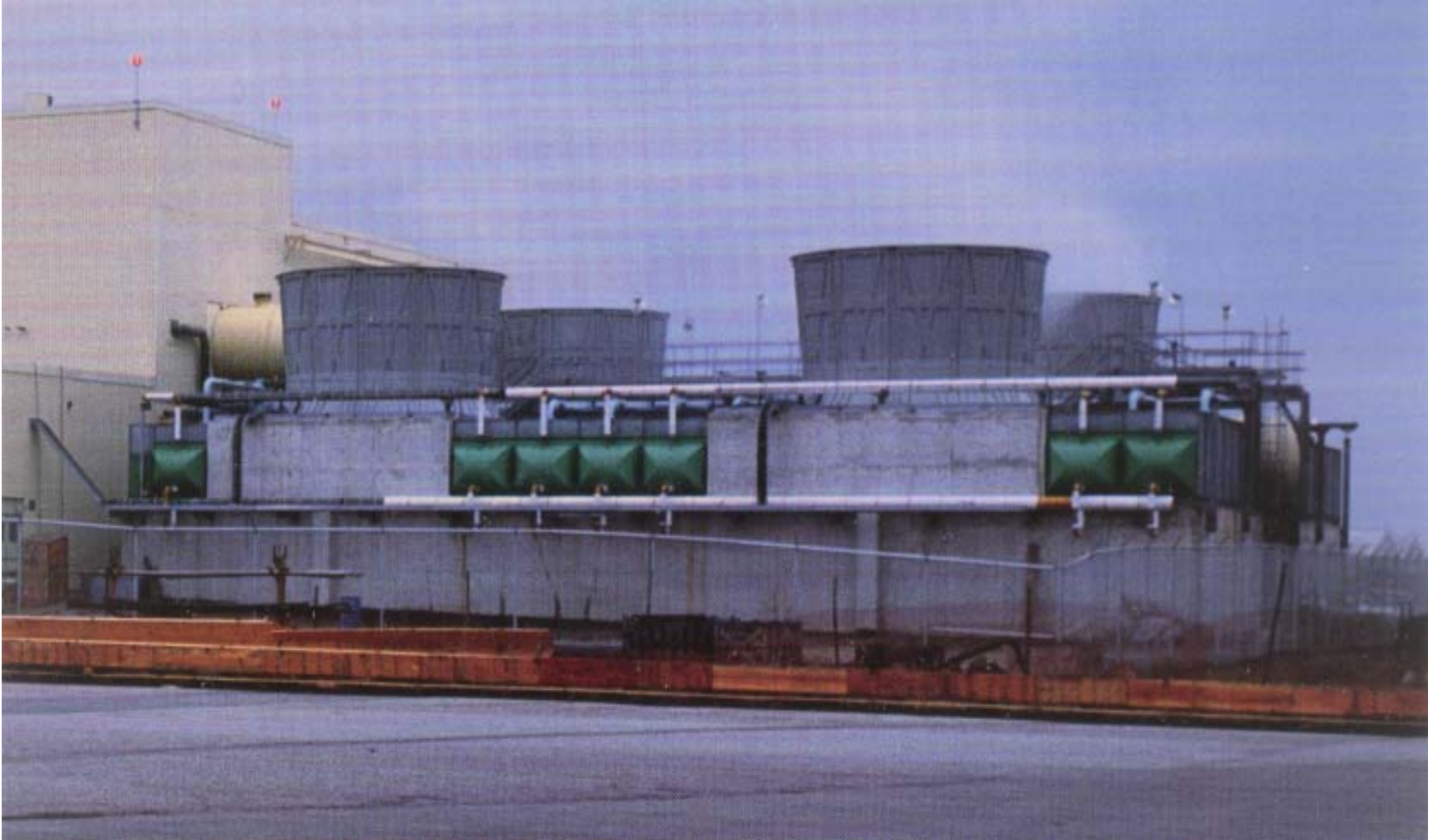
# **670,000 lb/hr Steam Condensers and** **Auxiliary Fluid Cooler**



# Steam Condenser With Remote Basin



# Steam Condenser



Condensing 240,000 lbs/hr of steam at 2.33"Hg Abs and cooling 1300 gpm of water for auxiliary cooling purposes.



**ACC**

An aerial photograph of a nuclear power plant facility. The central building is a large, light-colored structure with a tall, dark cylindrical stack. To the left of the main building are two large, horizontal, rectangular structures with a grid-like pattern, identified as the ACC. To the right of the main building is a large, open area with various electrical components and structures, identified as the TIAC COND. In the foreground, there are two large, cylindrical tanks, identified as the AUX LOOP COOLER. The facility is surrounded by a dense forest with autumn foliage in shades of red, orange, and yellow. A road or path runs along the bottom right of the facility.

**AUX LOOP  
COOLER**

**TIAC  
COND**

# Gas Turbine Inlet Air Cooling Components



# **12,000 TON AMMONIA CONDENSER GRIFFITH, AZ**



# **Advantages of Closed-Loop, Wet Surface Air Cooler Technology**

- Poor Quality Water can be used as makeup source
- Higher cycles of concentration (less discharge)
- Lower HP required / more available power to grid
- Maintains Thermal Performance Consistent over Time
- Lower installed cost

# **WATER (RESOURCE) CONSERVATION USING CLOSED-LOOP, EVAPORATIVE COOLING SYSTEMS FOR POWER PLANT APPLICATIONS**

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